ANALYSIS OF RADIATION EXPOSURE FOR OBSERVERS AND MANEUVER TROOPS

Exercise Desert Rock IV, Operation Tumbler-Snapper

Science Applications International Corporation P. O. Box 1303 McLean, VA 22102-1303

1 August 1985

Technical Report

CONTRACT No. DNA 001-85-C-0101

AUG 2 7 1986 DASIAC

Approved for public release; distribution is unlimited.

THIS WORK WAS SPONSORED BY THE DEFENSE NUCLEAR AGENCY UNDER RDT&E RMSS CODE B350085466 U99QMXMK00112 H2590D.

Prepared for Director DEFENSE NUCLEAR AGENCY Washington, DC 20305-1000

5 27

Destroy this report when it is no longer needed. Do not return to sender.

•

PLEASE NOTIFY THE DEFENSE NUCLEAR AGENCY, ATTN: STTI, WASHINGTON, DC 20305-1000, IF YOUR ADDRESS IS INCORRECT, IF YOU WISH IT DELETED FROM THE DISTRIBUTION LIST, OR IF THE ADDRESSEE IS NO LONGER EMPLOYED BY YOUR ORGANIZATION.



1

DISTRIBUTION LIST UPDATE

This mailer is provided to enable DNA to maintain current distribution lists for reports. We would appreciate your providing the requested information.

	Add the individual listed to your distribution list.	
	Delete the cited organization/individual	
	Change of address.	
NA	AME:	
OR	RGANIZATION:	
	OLD ADDRESS	CURRENT ADDRESS
TE	ELEPHONE NUMBER: _()	
SU	JBJECT AREA(s) OF INTEREST:	
DN	NA OR OTHER GOVERNMENT CONTRACT NUMBER:	
CE	ERTIFICATION OF NEED-TO-KNOW BY GOVERNMENT S	PONSOR (If other than DNA):
:	SPONSORING ORGANIZATION:	
(CONTRACTING OFFICER OR REPRESENTATIVE:	
1	SIGNATURE:	

Director Defense Nuclear Agency ATTN: STTI Washington, DC 20305-1000

> Director Defense Nuclear Agency Washington, DC 20305-1000 Washington, DC 20305-1000

UNCLASSIFIED SECURITY CLASSIFICATION OF THIS PAGE

	REPORT DOCU	MENTATION	PAGE		
1a REPORT SECURITY CLASSIFICATION		16 RESTRICTIVE	MARKINGS		
		3 DISTRIBUTION / AVAILABILITY OF REPORT			
N/A since Unclassified		Approved	for public	release:	distribution
26 DECLASSIFICATION/DOWNGRADING SCHEDU N/A since Unclassified	JLE	is unlin	nited.	· - · ,	
4 PERFORMING ORGANIZATION REPORT NUMBE	ER(S)	S MONITORING	ORGANIZATION R	EPORT NUMBE	R(S)
SAIC-85/1715		DNA-TR-8	35-277		
6a NAME OF PERFORMING ORGANIZATION	66 OFFICE SYMBOL	7a NAME OF M	ONITORING ORGA	NIZATION	
Science Applications	(if applicable)	Defense	r Nuclear Age	ncv	
	L		Hucrear Age	Codel	
D. D		10 ADDRESS (CI	ty, state, and zir		
McLean, Virginia 22102-1303		Washingt	ton, DC 2030	5-1000	
8a. NAME OF FUNDING / SPONSORING	86 OFFICE SYMBOL	9 PROCUREMEN	T INSTRUMENT ID	ENTIFICATION	NUMBER
ORGANIZATION	(if applicable)	DNA 001	L-85-C-0101		
8c. ADDRESS (City, State, and ZIP Code)	<u> </u>	10 SOURCE OF	FUNDING NUMBER	रऽ	
		PROGRAM	PROJECT	TASK	WORK UNIT
		62715H		ĸ	
13a TYPE OF REPORT 13b TIME C Technical 13b TIME C 16 SUPPLEMENTARY NOTATION This work was sponsored by B350085466 U99QMXMK00112 17 COSATI CODES FIELD GROUP 18 3 6 18	the Defense Nucl 590D. 18 SUBJECT TERMS (Operation Tu Exercise Des Radiation Ex	14 DATE OF REPO 8508 ear Agency u Continue on revers mbler-Snappe ert Rock IV posure Asses	DRT (Year, Month, 301 under RDT&E er Autom Nucle ssment (NT	Day) 15 PAC RMSS Code d identify by b ated Dose ar Test Pe PR)	5E COUNT 64 Nock number) Reconstruction ersonnel Review
19 ABSTRACT (Continue on reverse if necessary The radiation doses to obse reconstructed for each appl radiation doses are calcula troop activities to the rad parameter. Possible exposu The calculated film badge e Charlie) to 370 mrem (maneu all participants at all sho 20 DISTRIBUTION/AVAILABILITY OF ABSTRACT	and identify by block of rvers and maneur icable shot of C ted by using an iation environme re to initial ra quivalent doses ver troops, Shot ts.	ver units for operation Tun automated pr ent. Uncerta diation and range from 1 Dog). Init	Dr Exercise nbler-Snappe rocedure to ainties are internal do 11 mrem (par tial doses w	Desert Roc r (1952). couple sce determined ses are al atroop uni ere neglig	ck IV are Residual enarios for I for each so assessed. ts, Shot gible for
		UNCLAS	SIFIED		
Betty L. Fox		226 TELEPHONE	Sinclude Area Code 0-7042	DNA/S	STTI
DD FORM 1473, 84 MAR 83 A	PR edition may be used us All other editions are o	ntil exhausted bsolete.	SECURITY	CLASSIFICATIO	N OF THIS PAGE

UNCLASSIFIED SECURITY CLASSIFICATION OF THIS PAGE

•

UNCLASSIFIED SECURITY CLASSIFICATION OF THIS PAGE

TABLE OF CONTENTS

Sect	tion		Page
	LIST	OF ILLUSTRATIONS	iv
	LIST	OF TABLES	v
1	INTF	RODUCTION	1
2	OPE	RATIONS	5
	2.1	SHOT DATA	5
	2.2	PARTICIPATION	5
	2.3	CONCEPT	7
	2.4	ACTIVITIES	12
3	INIT	IAL RADIATION	26
4	RES	IDUAL RADIATION	27
	4.1	RESIDUAL GAMMA EXPOSURE	27
	4.2	INTERNAL RADIATION EXPOSURE	31
	4.3	RESIDUAL RADIATION DOSE SUMMARY	34
5	UNC	ERTAINTY ANALYSIS AND TOTAL DOSE DETERMINATION	35
	5.1	UNCERTAINTIES IN RESIDUAL RADIATION DOSE	35
	5.2	TOTAL DOSE SUMMARY	39
6	FILN	A BADGE DOSIMETRY	41
7	CON	ICLUSIONS	42
8	LIST	OF REFERENCES	43
	AVAI	LABILITY INFORMATION	46

LIST OF ILLUSTRATIONS

Figure		Page
1	Shot locations, Operation Tumbler-Snapper	2
2	Shot Charlie area	14
3	Shot Dog area	18
4	Shot Fox area	21
5	Shot George area	23
6	Shot Charlie residual radiation and observer and maneuver troop routes	29
7	Shot Dog residual radiation and maneuver troop routes	30
8	Shot Fox residual radiation and observer routes	32
9	Shot George residual radiation and observer and maneuver troop routes	33

LIST OF TABLES

Table		Page
1	Shot data, Operation Tumbler-Snapper	6
2	Observer participation, Exercise Desert Rock IV	8
3	Maneuver troop participation, Exercise Desert Rock IV	9
4	Dose summary, Operation Tumbler-Snapper	40

.

SECTION 1 INTRODUCTION

This report is an analysis of the nuclear radiation exposure for military participants in the 1952 series of nuclear tests at the Nevada Proving Ground (NPG) (presently called the Nevada Test Site). The series was designated Operation Tumbler-Snapper.

Operation Tumbler-Snapper consisted of 8 shots (Figure 1), detonated over a period of nine weeks in the spring of 1952. Exercise Desert Rock IV, conducted in conjunction with Operation Tumbler-Snapper, consisted of military activities at four of the tests, Charlie, Dog, Fox, and George.

There were three types of military participation in Exercise Desert Rock IV. The first consisted of troop observers, who were military personnel sent to Camp Desert Rock for the specific purpose of observing one or more nuclear shots. Troop observers participated in Shots Charlie, Dog, Fox, and George.

The second type of military participation consisted of battalion-size maneuver units that moved to Camp Desert Rock for the purpose of engaging in tactical exercises to test doctrine and tactics being developed for the nuclear battlefield. Two such exercises were conducted: an Army Battalion Combat Team (BCT) and two Provisional Air Force Squadrons maneuvered at Shot Charlie and a Marine Corps Provisional Exercise Unit maneuvered at Shot Dog.

Third, there were the personnel assigned to Camp Desert Rock, usually for the entire exercise, who planned, supported, and administered the overall exercise. Some of these support elements participated in shots as observers or maneuver units, e.g., the Army Engineer Amphibious Support Regiment that was assigned to Camp Desert Rock also maneuvered at Shot George. Some Camp Desert Rock support personnel also witnessed Shots Able, Baker, and Easy, but from a great distance; these activities were not part of Exercise Desert Rock IV.



Figure 1. Shot locations, Operation Tumbler-Snapper.

- -

1

It should be noted that a fourth major category of military participation, not a part of Exercise Desert Rock, consisted of projects conducted under the sponsorship of Field Command, Armed Forces Special Weapons Project. These efforts, as well as the support provided by Department of Defense personnel to other test groups and to the overall operation, are to be analyzed as necessary to supplement available film badge dosimetry.

Activities for each of the shots are traced from the pre-shot orientation through the shot activities, including any tactical maneuver and post-shot equipment inspection. Time-dependent position information is presented in order that an exposure analysis can be performed to determine the integrated dose from all contributing sources, principally the external dose due to residual radiation from the shot and applicable preceding shots.

The analysis utilizes an automated procedure, developed previously (Reference 2) for determining the external dose due to residual radiation. Radiological survey data are fit, in statistical regression analyses, to space-time models of residual radiation intensity, from which isointensity contours (isopleths) are then developed.

As in previous reports, the methodology also considers the effect of soil activation in the residual radiation analysis. This is particularly important for Shots Charlie and Dog, where the residual contamination of the post-shot times of interest was primarily due to the neutron-induced activity of Manganese-56 and Sodium-24. For some other shots, the induced contribution was evident near ground zero, but at greater distances it was small compared to the contribution from fission products. In all cases, the decay model is representative of actual shot conditions, verified by correlations with available data.

Comparison is made between calculated dose and available film badge records. The methodology for determining personnel dose is essentially that used in previous analyses (References 2, 26, and 27), in which comparisons with dosimetric data established a high degree of confidence. The uncertainties in the results are due primarily to the uncertainties in both the radiological surveys and the time-position

3

descriptions of troop activities. Automation of the dose estimation procedure facilitates the determination of confidence levels and aids in subsequent exposure analyses of other troop operations in the same radiologically contaminated areas.

The major finding of this report is that the radiation doses for Exercise Desert Rock IV participants ranged from 11 mrem (Shot Charlie, paratroop unit) to 370 mrem (Shot Dog participants). All calculated doses are from residual radiation and are significantly less than the 3 rem maximum dose permitted for Exercise Desert Rock IV.

SECTION 2 OPERATIONS

2.1 SHOT DATA.

A summary of the eight test shots of Operation Tumbler-Snapper is contained in Table 1. To determine radiation exposure for participants, all shots are considered for any residual radiation that might have contributed to total radiation dose.

2.2 PARTICIPATION.

Exercise Desert Rock IV maneuver and observer troops consisted of an estimated 7,700 military personnel who arrived at Camp Desert Rock to participate in testing and training programs. These troops, unlike the Camp Desert Rock support troops, were assigned to Camp Desert Rock to participate in specific activities associated with a particular shot. These activities included the troop observer program and tactical troop maneuvers, both of which are treated in this report.

2.2.1 Observers.

There were three categories of observer personnel participating in Exercise Desert Rock IV. In addition, other military and civilian observers, sponsored by the Atomic Energy Commission or the Armed Forces Special Weapons Project, witnessed shots but generally did not participate in shot activities to the same extent as did Exercise Desert Rock personnel. The categories of Desert Rock observers were as follows:

<u>Service Observers.</u> This group consisted of personnel selected from all four military services. They were sent to Camp Desert Rock from military bases throughout the United States, as well as from some overseas areas, to become familiar with nuclear weapons and their effects. They usually observed a shot from the same location as maneuver troops (7000 yards from ground zero) and inspected the resulting damage to equipment exposed to the shot. The

SHC DESIGN AEC	OT ATION DESERT ROCK	DATE Actual (Sched)	LOCAL TIME (PDT)*	LOCATION COORDINATES (UTM)	BURST HEIGHT** (ft)	YIELD (KT)
ABLE	IV-1	l April (l April)	0900 (PST)	Frenchman Lake 950729	793 A	1
BAKER	IV-2	15 April (15 April)	0930 (PST)	Area 7 872044	1,109 A	1
CHARLIE	IV-3	22 April (22 April)	0930 (PST)	Area 7 871045	3,447 A	31
DOG	IV-4	1 May (29 April)	0930	Area 7 871044	1,040 A	19
EASY	IV-5	7 May (6 May)	0515	Area 1 798009	300 T	12
FOX	IV-6	25 May (13 May)	0500	Area 4 795056	300 T	11
GEORGE	IV-8	l June (20 May)	0455	Area 3 871004	300 T	15
ноw	IV-7	5 June (27 May)	0455	Area 2 784104	300 T	14

Table 1. Shot data, Operation Tumbler-Snapper.

*Unless noted as Pacific Standard Time (PST) **T = Tower, A = Air Drop Source: References 6, 7, 8 participation of the service observers is shown in Table 2. It should be noted that, due to possible participation in more than one shot, the numbers in each category are not necessarily additive. This is explained in Section 2.3. It should also be noted that the service observers did not engage in any maneuvers or other similar exercises while at Nevada Proving Ground.

<u>Camp Desert Rock (CDR) Observers.</u> This group consisted of Army personnel assigned to Camp Desert Rock as the permanent party--that is, those who planned, administered, and supported the maneuvers and programs (including the observer program) that comprised Exercise Desert Rock IV. They were permitted to observe one or more shots during their stay at Camp Desert Rock, but most likely not one of the four shots at which Desert Rock exercises were conducted.

<u>Civilian Observers.</u> These observers were apparently civil service employees from the various army areas who were sent to Camp Desert Rock in the same manner as other military service observers. Their number is unknown. There were many other civilian observers at NPG, not sponsored by Desert Rock, who participated in various shot-related activities.

2.2.2 Maneuver Troops.

Approximately 4,900 exercise troops took part in the tactical maneuvers conducted at Shots Charlie, Dog, and George. Units from the Army, Marine Corps, and Air Force traveled to NPG specifically to participate in the maneuvers. In addition to these personnel, Camp Desert Rock support troops were utilized to form the maneuver elements for Shot George. Table 3 gives the total number of participants in the maneuvers at each shot.

2.3 CONCEPT.

The purpose of Exercise Desert Rock IV was to provide indoctrination and training in military operations involving tactical employment of nuclear weapons; to

Table 2. Observer participation, Exercise Desert Rock IV.

Shot	Army	Navy	Marine Corps	Air Force	Total ⁺ Observers
CHARLIE	300			200	500
DOG		50*	300*		350*
FOX	1450				1450
GEORGE	550 (est.)				550 (est)

8

*References report a total of 350 personnel from the Navy and Marine Corps. The breakdown by individual service is an estimate.

+Does not include an unknown number of DoD personnel who observed the tests but not as part of Exercise Desert Rock.

Source: References 1, 6, 7, 9

Table 3. Maneuver troop participation, Exercise Desert Rock IV.

Participating	Shot				
Service	CHARLIE	DOG	FOX	GEORGE	
Army	700				
Marine Corps		1950			
Air Force	325				
Camp Desert Rock Support Troops (Army)	500			1400	
					
Total Participants	1525	1950		1400	

Source: References 4, 7, 9, 10, 11

demonstrate to participating maneuver troops and observers the effects of nuclear explosions on prepared positions and equipment; to determine psychological reactions of participating troops; and to determine the type and amount of indoctrination in nuclear warfare required for all personnel.

In general, Exercise Desert Rock IV was a continuation of the military exercises conducted in conjunction with Operation Buster-Jangle. For Operation Tumbler-Snapper, the US Army was given substantial responsibility for radiological safety of participating Desert Rock IV personnel. The Desert Rock IV operation plans provided for witnessing the shots from closer distances than in previous exercises while allowing participants to conduct somewhat realistic military exercises within radiation limits. Subject to radiation constraints, troop maneuvers were allowed near ground zero as long as there was no interference with instrumentation or other experiments.

Observers and maneuver troops generally participated together in activities that included the following:

o Pre-shot classroom instruction.

Subjects included basic nuclear theory, characteristics and effects of nuclear weapons, protective measures to employ against a nuclear attack, tactical use of nuclear weapons, and a plan of operation for the upcoming shot. Eight hours of instruction were planned. For those observers who did not arrive at Camp Desert Rock in time for the instruction, a one-hour orientation was conducted on the evening preceding the shot.

o Rehearsal of shot day activities.

Observers visited the trenches, had a "dry run" of the detonation, and then viewed the display area established for the shot. In some cases, they were taken to the display area of a previous test to see the post-shot effects. Maneuver troops rehearsed their activity and then viewed the display area.

o <u>Shot observation</u>.

Approximately one hour before the scheduled shot, observers arrived at the trench area, were briefed on what to expect, and were checked for proper

10

safety procedures. A few minutes before the shot, they entered the trenches and assumed a crouching position.

<u>Guided tour through display area.</u>
 Under the direction of the Desert Rock control group, observers toured the equipment display area to see and have explained the effects of the detonation on animals, equipment, and prepared positions.

In addition, the maneuver troops participated in a tactical maneuver involving an attack on an objective in accordance with the exercise plans. The troops were accompanied by radiological safety monitors and preceded by radiological survey teams who determined the limits of safe advance. After reaching their objective or approaching as close as radiation safety standards would permit, the maneuver was terminated. Under the direction of the Desert Rock control group, the troops would then inspect the display area. After they viewed the display areas, both maneuver troops and observer groups returned to Camp Desert Rock.

For radiological safety purposes, a maximum permissible dose of 3 rem was established for the entire exercise (Reference 1). The 500 mr/hr intensity line was the limit of advance for the troops unless otherwise authorized by the Commanding General, Camp Desert Rock. Standard operating procedures for radiological safety in all operations were based on these criteria.

Film badges were to be issued to all participants the day before the shot and collected on shot day. Shortly after the passage of the shock wave, Army rad-safe monitors were to precede the troops and survey the contaminated area. Unless otherwise noted, observer and maneuver activities in the shot area would begin with the completion of the surveys and the declaration of recovery hour (R-hour) by the AEC. Before leaving the forward area, participants and vehicles were to be brushed with brooms and then monitored (usually at the parking area) to ensure compliance with radiation limits. Any person or vehicle with radiation intensity greater than 10 mr/hr was to be sent to the decontamination station at Yucca Pass. Personnel sent to Yucca Pass were to shower and put on clean clothes; all vehicles were to be washed.

11

On return to Camp Desert Rock, all personnel were to shower and put on clean clothing and were then to be monitored to ensure compliance with limits of 1.5 mr/hr for clothing, and 0 mr/hr for skin. All contaminated vehicles were to be decontaminated to background count. (References 1, 12).

2.4 ACTIVITIES.

Shot data for Operation Tumbler-Snapper are listed in Table 1. Weather or technical difficulties altered the general schedule in several of the shots. For all shots, participants departed Camp Desert Rock for the trench area in convoys of buses and trucks. All participants occupied the same set of trenches at a given shot. When a unit made a post-shot inspection of equipment displays, movement to and through the display area was normally accomplished as a single group. Ground zero locations, the trench locations, and the display areas are identified on the figures accompanying the discussion of each shot. The following paragraphs describe the activities for each shot.

2.4.1 Shot Charlie.

<u>Observers</u>. Observers for Shot Charlie consisted of approximately 300 Army personnel from the six continental armies and military service schools and approximately 200 Air Force personnel (Reference 9). Most observers reported for duty between 18 and 21 April (Reference 13). Observers were integrated with troop units in indoctrination and in witnessing the explosion (Reference 1).

On 19 April, three days before the shot, observers rehearsed their shot-day activities, proceeding into the trenches and inspecting the equipment display areas. From 19 to 21 April, the Instructor Group used films and lectures to familiarize the observers with the characteristics of a nuclear detonation and safety procedures to follow during a nuclear test (Reference 13).

At about 0500* hours on shot day, observers began leaving Camp Desert Rock by motor convoy for the trench area. All observers were in the trench area by 0816 hours (References 1, 14). At about an hour before the shot, a Camp Desert Rock instructor conducted a final briefing, describing shot time procedures and safety precautions. Ten minutes before the shot, all personnel were ordered into the trenches and foxholes, 7000 yards south of the intended ground zero (see Figure 2). Two minutes before the 0930 shot, the Exercise Director ordered all participants to crouch, cover their faces with their hands, and lean against the forward wall of the trenches. Three seconds after the flash, the troops were allowed to stand and observe the rising fireball. About 15 seconds later, the shock wave reached the trench area, temporarily obscuring vision. About 25 minutes later, Army rad-safe monitors moved forward to survey the contaminated area (Reference 1). The observers remained in the trench area while the survey was conducted (Reference 13). At 1027 hours, recovery hour was declared by the AEC (Reference 15), and at 1030 hours observers boarded trucks and moved into the shot area (Reference 1). The convoy traveled north on to BJY and proceeded to parking area F, stopping to unload the troops about 3500 yards from GZ (Reference 13). The observers began their tour of the equipment display area on foot at about 1100 hours, advancing to each display and stopping to observe the effects of the explosion. The equipment displays were located at 3500, 1700, 900, 550 and 200 yards from ground zero, as shown in Figure 2 (Reference 1). The observers reached the 200-yard display area at approximately 1215 hours. They then returned to the vehicle parking area and were monitored for contamination. At approximately 1330 hours, the observers boarded their vehicles and left for Camp Desert Rock, where they arrived at about 1530 hours.

<u>Maneuver Units</u>. Maneuver units for Shot Charlie consisted of an Army battalion combat team (BCT) and two Air Force squadrons, made up of approximately 1525 troops as follows:

^{*}All times for Shot Charlie are Pacific Standard Time (PST)





Company F, 504th Regiment, 82d Airborne Division Company H, 504th Regiment, 82d Airborne Division Company B, 165th Infantry Regiment, 31st Infantry Division Company C, 135th Infantry Regiment, 47th Infantry Division 1 Tank Platoon, 11th Armored Cavalry (tanks provided by Camp Irwin) 1 Engineer Platoon, 369th Engineer Amphibious Support Regiment (EASR) 1 Medical Detachment, 369th EASR (augmented from Sixth Army) Approximately 400 additional troops from the 369th EASR (References 10, 11, 13, and 16)

The two Air Force squadrons were made up as follows:

- 187th Provisional Fighter-Bomber Squadron (comprised of personnel from the 140th Fighter-Bomber Group, the 140th Wing Headquarters and Headquarters Squadron, and the 140th Medical Group).
- 140th Provisional Maintenance Squadron (comprised of personnel from the 140th Maintenance and Supply Group and the 140th Air Base Group).

(Reference 17)

Maneuver elements reported to Camp Desert Rock by 18 April (Reference 13). From their arrival at Camp Desert Rock until they reached the 200-yard equipment display on their post-shot tour, the maneuver troop activities were the same as the observer activities, except for the paratroops (Company F, 504th Airborne Infantry Regiment), and tank crews, whose activities are described below.

Tank crews remained inside their tanks at the trench area (there is no record of a tank maneuver). The paratroops, numbering approximately 110-120 (Reference 11), were with the ground forces in the trench area for the detonation. Immediately after the shot, the paratroops loaded onto trucks and proceeded south to the Yucca Flat landing strip (Reference 15). They boarded several C-46 aircraft, which took off at 1050 hours (about 20 minutes after R-hour) for the ground zero area. A C-47 hospital aircraft accompanied the C-46 aircraft (References 17, 18). The planes took off to the southeast and made a large clockwise circle until they lined up with the drop zone northwest of ground zero. (The drop zone had presumably been declared radiologically safe for Desert Rock purposes by Army rad-safe monitors who accompanied AEC initial rad-safe survey teams.) The paratroops were supposed to begin parachuting at about 1115 hours into the drop zone shown in Figure 2 (References 15, 18). However, the paratroops in one C-46 jumped four minutes early and landed as far as 10 miles from the intended drop area, to the SW of ground zero (References 17, 18). Five paratroops were slightly injured on landing. The rest of the paratroops jumped as scheduled and, by 1120 hours, were either in descent or just reaching the ground (Reference 13). After landing, they proceeded south toward the display area, while the other maneuver troops were proceeding to the north along the same line. At about 1220 hours, approximately 600 yards from ground zero, the two elements would have met. They then would have marched back to the display area and from there to parking area F, where they would have arrived at about 1320 hours. Before leaving the parking area, all personnel were monitored to ensure compliance with radiation limits. The observers and maneuver units left by motor convoy for Camp Desert Rock at about 1330 hours, arriving by 1530 hours.

2.4.2 Shot Dog.

Approximately 350 Navy and Marine Corps personnel were present at Shot Dog as observers (Reference 6). Most reported to Camp Desert Rock between 24 April and 28 April (Reference 13).

Two Marine Corps provisional battalions, totaling about 1,950 troops, also participated at Shot Dog (Reference 9). The 1st Provisional Marine Battalion, from Camp Pendleton, California, arrived on 23 April (Reference 13). It was made up as follows:

H&S Co Medical and Clearing Platoon Weapons Co Rifle Co Weapons Co Rifle Co

Provided by

Force Troops 3rd Marine Division Force Troops 3rd Marine Division 3rd Marine Division AirFMFPac

Total planned strength: 1000 (estimated)

(Reference 19)

The 2nd Provisional Marine Battalion from Camp Lejeune, North Carolina, arrived on 24 April (Reference 13). It was made up as follows:

A.C. 511

		OII	EM
H & S/Co, InfBn (Prov)	Force Troops	12	116
Bn Augmentation	FMFLant		
MedSec	2dMarDiv		
Cir Plat, Coll&CirngCo	2dMarDiv		
Rifle Co (Prov)	2dMarDiv	7	221
Rifle Co (Prov)	2dMarDiv	7	221
Rifle Co (-1 Plat)(Prov)	Force Troops	6	177
Rifle Co (-1 Plat)(Prov)	AirFMFLant	6	177
TOTALS		38	912
		(Refere	nce 5)

The observers, together with the two battalions, were formed into a Marine Corps Provisional Exercise Unit for Shot Dog. In the days between their arrival and the shot, troops participated in pre-shot orientation, including lectures and a full rehearsal of shot-day activities on 27 April (Reference 19). At 0633* hours on shot day, the troops left Camp Desert Rock by motor convoy. They arrived in the trench area at about 0820 hours (Reference 19). Shortly thereafter, a Camp Desert Rock instructor began briefing the troops on shot-time procedures. Ten minutes before the shot, the troops entered the trenches and foxholes (Reference 20), 7000 yards south of ground zero (see Figure 3). The 1st Provisional Battalion was on the right and the 2nd Provisional Battalion was on the left (Reference 21). Observers were likely in the center with the control element. Two minutes before the shot, all personnel crouched down in the trenches. The shot went off at 0930 hours as scheduled. Three seconds after the flash, the troops were permitted to stand in the trenches to observe the rising fireball (Reference 20). The reference also states that, with the passage of the blast wave, maneuver personnel left their cover and moved forward as if jumping off in the attack. This movement did not continue; the major forward movement was by truck. Immediately following the shot, the Marine Corps radiological safety party accompanied the Camp Desert Rock radiological parties on the initial survey of the display area. At 1051 hours, R-hour was declared by the AEC. Thirty minutes later, all personnel traveled by truck convoy to parking area F, where they

^{*}All times for Shot Dog are Pacific Daylight Time.



Figure 3. Shot Dog area.

arrived about twenty minutes later. At about 1150 hours, the troops began their tour of the equipment display areas, located 1700-1750, 900-1000, and 300- 400 yards from ground zero (see Figure 3). A "special position" at 1300 yards contained only dummies clad in uniforms (Reference 21). The troops advanced to the first two areas and stopped at each to view the effects of the explosion on the equipment. Near the 900-yard display, the troops would have reached the 500 mr/hr level, the usual limit for forward advance. Evidently, they were permitted to proceed closer to GZ, as Reference 20 states that "the radiation intensity at position 1, that nearest ground zero, was such that a decision was made not to enter the position but view it from a distance of about 100-200 yards." At this distance from the outermost displays of position 1, personnel would have been 500-600 yards from ground zero.

After halting their advance, the troops returned to the parking area, where they arrived at about 1345 hours (References 20, 21). References 20 and 19 state that, upon return to the parking area, each individual was monitored and, as all readings were well below the prescribed 10 mr/hr, motor serials were dispatched for the return to Camp Desert Rock as soon as they were loaded. The troops probably arrived at Camp Desert Rock at about 1530 hours (References 20, 21). Film badges were collected on return. Troops returned to their home units on 2 May (Reference 19).

2.4.3 Shot Fox.

Exercise Desert Rock IV participation at Shot Fox consisted of approximately 500 observers from the six continental armies and service schools, and approximately 950 observers from the 701st Armored Infantry Battalion (AIB), First Armored Division, Fort Hood, Texas (including Companies A, B, C, and D) (References 1, 6, 9, and 22). There was no tactical maneuver at Shot Fox (Reference 23).

Shot Fox was originally scheduled to be detonated on 13 May, but due to poor weather conditions and a 20 May misfire, the detonation did not occur until 25 May. The 701st AIB, which was planning to participate in the rescheduled Shot George, arrived at Camp Desert Rock on 22 May. On 23 May, the Office of Chief of Army Field Forces directed that the 701st AIB participate in Shot Fox instead of the 369th Engineer Amphibious Support Regiment, the unit originally scheduled for participation at Shot Fox. This was probably done to minimize the time that the 701st spent at Camp Desert Rock waiting for a shot. The 369th, being a Camp Desert Rock support unit, could conveniently participate in either shot. The 369th EASR participated in Shot George instead (Reference 6).

All observers at Shot Fox participated in the same activities and are treated as a single unit. On 23 May, the observers attended four hours of lectures probably covering nuclear weapons effects, protective measures, and the plan for the shot. On 24 May, the observers participated in a rehearsal of shot day activities. They left Camp Desert Rock at 1220 hours* and probably arrived in the entrenchment area, 7000 yards southeast of ground zero, at about 1400 hours (see Figure 4). While in the trench area, they were briefed on what to expect on shot day; they then practiced entering the trenches and taking protective measures during a simulated burst. At about 1530 hours, the troops inspected the equipment display areas to view their preshot condition (Reference 22).

On shot day, the observers left Camp Desert Rock by motor convoy at 0150 hours, arriving in the trench area at about 0320 hours. About an hour before the shot, Camp Desert Rock instructors briefed the troops. At 0450 hours, the troops entered the trenches. Two minutes before the shot, the troops were ordered to crouch and lean against the forward trench wall. The detonation occurred at 0500 hours as scheduled. Five seconds after the detonation the troops were permitted to stand in the trenches and observe the rising nuclear cloud (Reference 22). Twenty seconds after the detonation, the shock wave passed over the observer trenches (Reference 24). The monitors immediately advanced to survey the shot area (Reference 16). R-hour was declared at about 0720 hours (Reference 22).

At 0730 hours, the observers loaded into trucks and traveled in convoy to parking area K, where they arrived at about 0805 hours. Their route took them north past BJY, then west to the parking area. The observers detrucked at about 0815 hours to

^{*}All times for Shot Fox are Pacific Daylight Time.





begin their inspection of the equipment displays located 3500, 1700, 900, 550, and 200 yards from ground zero, to the extent consistent with rad-safe criteria (References 1 and 22). The observers then returned to their vehicles at the parking area, at about 1020 hours (Reference 1). Before leaving for Camp Desert Rock, all personnel and vehicles were monitored for contamination. The troops departed parking area K by motor convoy at about 1100 hours, arriving at Camp Desert Rock at about 1300 hours.

2.4.4 Shot George.

<u>Observers</u>. Original plans called for Shot George to be detonated in Area 2, but residual radioactivity from Shots Easy and Fox delayed preparation of the area. Consequently, the Test Manager decided to detonate George in Area 3 and use Area 2 for Shot How (Reference 24).

Observers for Shot George consisted of 450-650 personnel from the six continental armies and military service schools (References 1, 7). Most observers arrived at Camp Desert Rock between 16 and 19 May. All observers took part in the same orientation and training activities (Reference 24).

The week before the detonation, the observers rehearsed their shot-day activities, including an inspection of the equipment display area (Reference 24). On shot day, the observers left Camp Desert Rock at 0220 hours* by motor convoy and arrived in the trench area 7000 yards south of GZ before 0400 hours (Figure 5). For the next hour, Camp Desert Rock instructors briefed the troops on shot-time procedures. Both the observers and maneuver troops occupied the same set of trenches (Reference 1). Two minutes before the shot, the instructor ordered all personnel to crouch, cover their faces with their hands, lean against the forward trench wall, and remain below ground level until after the detonation. The shot was detonated on schedule at 0455 hours. Three seconds after the flash, the troops were allowed to stand and observe the

^{*}All times for Shot George are Pacific Daylight Time.



Figure 5. Shot George area.

rising fireball (Reference 24). About 20 seconds after the shot, the shock wave reached the trench area (Reference 24). Immediately after the shot, Army monitors moved forward to survey the contaminated area and mark the 500 mr/hr line, the limit of advance. Recovery hour was declared at 0705 hours (Reference 15). At 0710 hours, the observers left the trench area by motor convoy for parking area P, where they arrived about 30 minutes later. They began their walk-through of the equipment display areas at about 0750 hours. The equipment displays were located 1700, 900, 550, and 500 yards from ground zero. Fabric and clothing samples were located 1800 and 2800 yards from ground zero (Reference 1). The troops stopped at each display that they got to and observed the effects of the detonation on the equipment. Due to radiation intensities, the 900-yard display area was the closest that troops were able to approach to GZ. After viewing this display area, the observers returned to parking area P, where all personnel and vehicles were monitored for contamination before departure. The observers departed parking area P by motor convoy at about 0940 for Camp Desert Rock, where they arrived at 1100.

Maneuver Units. Maneuver units for Shot George consisted of:

369th Engineer Amphibious Support Regiment (minus Boat Battalion)

Headquarters and Service Company Headquarters and Headquarters Company, Shore Battalion Companies D, E, and F 31st Transportation Truck Company Tank Platoon, First Armored Division

(References 1, 9, and 10)

Approximately 1400 troops participated in the maneuver (References 1 and 7). In the days preceding the shot, Camp Desert Rock instructors presented an indoctrination of nuclear weapons effects, protective measures, and the plan for shot day. The week before the shot, the troops rehearsed their shot day activities.

On shot day, the maneuver units left Camp Desert Rock by motor convoy at about 0155 hours. They arrived in the trench area two hours later (Reference 1). Until they began their post-shot maneuver, the maneuver troops followed the same scenario as the observers, except that tank crews remained inside their tanks, near the trenches, for the detonation. Because of the proficiency demonstrated by Army radiation monitors at previous shots, Desert Rock commanders were authorized to commence maneuvers immediately after the shock wave, with monitors to ensure radiological safety, rather than wait for the usual declaration of R-hour by the AEC (References 1 and 7). The maneuver units on foot were led by five tanks and followed by the vehicles that had brought them to the trench area (Reference 1). The troops reached their objective (see Figure 5) and, as radiation levels were low there, continued their advance. The tanks, however, are judged to have followed the original plan and turned left at the objective to proceed to parking area P. Due to the sensitivity of the display and scientific experimental areas, any deviation from the planned movement would almost certainly have not been permitted for the tanks. At about 0645 hours, the troops reached a radiation intensity of 500 mr/hr, the limit for forward advance (References 1 and 7). The troops moved laterally to the 900-yard equipment display area, arriving there at about 0655 hours (Reference 20). After viewing the effects of the detonation on the equipment, the troops moved to the 1700yard equipment display. They then moved to parking area P, where the trucks were waiting, arriving there at about 0745. All personnel and vehicles were then monitored. The troops departed parking area P at about 0815 by motor convoy, arriving at Camp Desert Rock at about 0940.

SECTION 3 INITIAL RADIATION

No military personnel were located closer than 7,000 yards from any detonation. Previous calculations have established that, for the type of devices detonated at Operation Tumbler-Snapper, there would have been a negligible (less than 0.001 rem) initial dose for personnel at this distance, whether in trenches or in the open (Reference 25).

SECTION 4 RESIDUAL RADIATION

4.1 RESIDUAL GAMMA EXPOSURE.

External gamma doses are reconstructed for observers and maneuver troops, based on their activities in the fallout and neutron-induced activity fields of Shots Charlie, Dog, Fox, and George. A computerized methodology, described in Reference 2, determines the radiological environment for each shot of interest. From this, doses are calculated based on the scenario of activities. Iso-intensity contours with superimposed troop tracks are displayed for each shot.

The computer-calculated doses do not reflect the presence of the human body in the radiological environment. Despite the penetrating ability of gamma rays from fission and activation products, the body affords some shielding; hence, the gamma dose to any organ depends on the geometry of the radiation source and the body position. In order to represent reconstructed film badge readings, gamma doses are calculated for the surface of the chest, where a film badge is normally worn. The calculated film badge dose rate is related to the free-field gamma intensity through the conversion factor developed in Reference 26: 1 R/hr — 0.7 rem/hr.

Observer dose calculations are categorized by the shot in which each observer group participated. Contributions from previous shots to the dose are noted as they arise.

Because of limited data concerning the details of display inspection and the timing involved, estimates are required for various parameters. Rates of movement are estimated from planned times or the few reported times, the number of displays viewed, the calculated or reported position of radiological safety limits, and the consequent distance to be traversed. A reasonable and consistent set of parameters is 50 yds/min walking speed between displays (including the starting and stopping of troops), 5 minutes at each display and at the limit of march toward GZ, and 70 yds/min on the return. Speeds for motor movements are taken from the operation plans or estimated from road conditions and vehicle type.

27

4.1.1 Shot Charlie.

The Charlie residual radiation contours are nearly circular and symmetric, typical of the neutron-induced activity of a high air burst. The radiation intensities were very low--the closest contour shown in Figure 6 represents the 10 mr/hr level. Therefore, rad-safe criteria played no constraining role in post-shot activities. Based on the scenario described in Section 2, it is calculated that the ground troops received a film badge dose of 19 mrem during their movement through the display areas and to the rendezvous point with the paratroops. Because the Charlie cloud drifted out of range before the aircraft took off, the paratroops would have received no dose while in the aircraft or in descent. During their movement to the rendezvous point, the paratroops received a dose of 2 mrem. During their movement together back to the parking area, the maneuver troops received a dose of 9 mrem. Therefore, the ground troops received a total dose of 28 mrem, and the paratroops a total dose of 11 mrem. The observers, moving as described in Section 2, received a dose of 19 mrem.

4.1.2 Shot Dog.

As seen in Figure 7, the radiation contour lines are nearly circular and symmetric, typical of neutron induced activity of an air burst. The maneuver and observer elements advanced together and would have reached the 500 mr/hr line, the usual limit for forward advance, at about 900 yards from ground zero. However, Reference 20 states that troops advanced to within 100-200 yards of the display area nearest ground zero. This would have placed the distance of closest approach at about 500 yards from ground zero, where the radiation intensity would have been about 5 R/hr. Available documentation has indicated the possibility of advancing past 0.5 R/hr if so ordered by the Desert Rock Commanding General (after consulting with radsafe personnel). Moreover, the 0.5 R/hr intensity restriction may not have applied to the Marine Corps maneuver. In Operation Upshot-Knothole (1953), the Marine Corps maneuver had a limit different from that of other troop activities (Reference 27), but no positive indication of a similar limit for this operation exists in available documentation.







Based on the foregoing scenario, the residual gamma film badge dose for the forward elements was 370 mrem.

4.1.3 Shot Fox.

Radiation contours for Shot Fox are shown in Figure 8. Calculations show that the troops would have reached the 500 mr/hr line about 100 yards before arriving at the 550-yard equipment display area. However, the intensity at this display would have been less than 800 mr/hr, and it is possible that a decision was made to view the display. In order to consider this possibility, it is assumed that the troops did advance to the 550-yard display. Based on this scenario, Shot Fox participants received a film badge dose of 126 mrem.

4.1.4 Shot George.

Radiation contours for Shot George are shown in Figure 9. It is not clear from the available records whether the maneuver troops stopped their advance at their objective, some 2500 yards south of ground zero, as planned, or continued their advance beyond the objective. The radiation intensity at the objective would have been less than 10 mr/hr. The maneuver troops could have advanced to the 500 mr/hr line, which would have been about 850 yards from GZ, then moved about 500 yards laterally along the isopleth to the 900-yard display area and then the 1700-yard display. Based on this scenario, the calculated film badge dose for the maneuver troops is 106 mrem. The observers, moving as described in Section 2, received a film badge dose of 28 mrem.

4.2 INTERNAL RADIATION EXPOSURE.

While operating in residual radiation fields, participants were subject to an internal dose commitment from the inhalation of airborne radionuclides. The internal dose pathways are resuspension of fresh fallout and suspension of neutron-activated soil while marching. Internal dose commitments for maneuver troops and observers, investigated and reported in Reference 28, are shown to be 150 mrem or less for a 50-year bone dose commitment.







Figure 9. Shot George residual radiation (R/hr @ H+1) and observer and maneuver troop routes.

4.3 RESIDUAL RADIATION DOSE SUMMARY.

The calculated film badge doses (mrem) to Exercise Desert Rock IV personnel are summarized below:

	<u>Shot</u>				
	CHARLIE	DOG	<u>FOX</u>	GEORGE	
Observers	19	370	126	28	
Ground Maneuver Troops	28	370	N/A	106	
Paratroops	11				

SECTION 5

UNCERTAINTY ANALYSIS AND TOTAL DOSE DETERMINATION

The sources of error in the calculation of residual doses are examined in order to quantitatively estimate the uncertainty in the dose for each unit. The approach for quantifying the uncertainty follows that for previous analyses. References 26 and 27 give a more comprehensive treatment of the methodology.

5.1 UNCERTAINTIES IN RESIDUAL RADIATION DOSE.

The uncertainty in calculated residual radiation doses arises from two basic sources: (1) gamma radiation environment, and (2) the space-time scenario of troop movements. The 90-percent confidence limits in the gamma intensity, including the uncertainty in the decay exponent and the time-space variations in troop scenarios, are facilitated through parametric studies using an automated dose determination procedure developed in previous analyses (Reference 2).

In the display areas, the limits of advance were not always reported. When the references do not report which equipment display lines were inspected, the assumption is made that all of the displays within rad-safe limits were inspected. The dose accrued within the display area is usually maximized if the innermost display visited is coincident with the rad-safe limit. Within the uncertainty of the radiation field, this is often a possibility.

The timing of the troops' march is generally based on the planned time of attack, time of arrival at the objective, and arrival at the pickup point. Reasonable march speeds and display area stay times are assumed, in order to construct a scenario consistent with the planned times. The most important influence of timing on the uncertainty in dose is the time spent at the position(s) of greatest gamma intensity. Uncertainties based on timing are high-sided by coupling stay times (all upper limits are considered together) and by ignoring the overall time constraint on the combination of long stay times and slow march speeds. The various sources of error are combined approximately; they cannot be combined rigorously due to the disparity of their associated distributions. While some distributions are normal as expressed (e.g., a march speed ± 10 yds/min or a halt point ± 100 yards from GZ), they imply a more lognormal distribution in dose. For each source of uncertainty, the limits on dose are interpreted in terms of error factors on the best-estimate doses from Section 4. Uncertainties are combined as for lognormal distributions. The overall uncertainties permit determination of the mean dose from residual radiation for each shot. Only for significantly skewed distributions is the mean much different from the best estimate. For multiple exposures, the means may be legitimately added to find the mean total dose, which may be compared to film badge data or entered as an individual's assigned gamma dose. Ninety-percent confidence limits are estimated for each calculated dose.

5.1.1 Shot Charlie.

<u>Paratroops</u>. Uncertainty in the residual radiation dose for Shot Charlie Paratroop units stems from two sources: (1) the residual radiation field and (2) marching speeds. The marching speed for the paratroops was taken to be 70 ± 10 yds/min. The calculated film badge doses, with uncertainties, are:

Source of Uncertainty

Residual	March	
Field	Speeds	Combined
11 +2 -2	11 <mark>+2</mark> -2	11 +3 -2

<u>Ground Troops</u>. Uncertainty in the residual radiation dose for Shot Charlie maneuver units stems from three sources: (1) the residual radiation field, (2) marching speeds, and (3) stay times at the equipment display areas. Marching speeds were taken to be 50 ± 10 yds/min while marching between the display areas, and 70 ± 10 yds/min while marching to meet the paratroops and on return to the parking area. Stay times were taken to be five minutes with a factor of two variation. The calculated film badge doses, with uncertainties, are:

Source of Uncertainty

Residual	March	Stay	
Field	Speed	Times	Combined
28 ⁺⁷ -5	28 ⁺¹⁰ -8	28 <mark>+12</mark> - 8	28 ⁺¹⁷ -11

<u>Observers</u>. Uncertainty in residual radiation dose for Shot Charlie observers is due to the three same sources as for the maneuver troops. The calculated film badge doses, with uncertainties, are:

5.1.2 Shot Dog.

The main sources in uncertainty for Shot Dog are (1) the distance of closest approach to GZ, (2) marching speeds, and (3) the radiation field intensity. Based on available references, the distance of closest approach could be uncertain by as much as 100 yards--if the troops reached only 200 yards from the outermost display or 100 yards from the innermost display of position 1. Therefore, a distance of closest approach of 500 + 100 +

Source of Uncertainty

Distance of			
Closest	March	Residual	
Approach	Speeds	Field	Combined
370 <mark>+240</mark> -140	370 ⁺⁶⁰ -50	370 ⁺⁵⁰ -50	370 <mark>+260</mark> -1 <i>5</i> 0

5.1.3 Shot Fox.

Uncertainty in the residual radiation dose for Shot Fox stems from two sources: (1) time spent at the display areas, and (2) the reconstructed radiation contours. Stay times are assumed to be 5 minutes, with an error factor of 2. Most of the dose was accumulated at or near the 550-yard display area; thus march speeds and timing of activities contribute negligibly to overall uncertainty. March speeds were assumed to be 50 ± 10 yds/min during approach to GZ and 70 ± 10 yds/min during the return to the parking area. The calculated film badge doses, with errors, are:

Source of Uncertainty

Stay	Residual	
Times	Field	Combined
126 +47 -34	126 ⁺²³ -19	126 <mark>+54</mark> -38

5.1.4 Shot George.

<u>Observers</u>. The sources of uncertainty in dose reconstruction for the observers are from (1) the residual field intensity and (2) stay time at the 900-yard equipment display area. A stay time of five minutes was used for the computer reconstruction, but a stay time of as long as ten minutes is used for the 90-percent confidence limit. Uncertainty in other stay times, marching speeds, and activity times contribute negligibly to overall uncertainty. The calculated film badge doses, with uncertainties are:

Source of Uncertainty

Residual	Stay	
Field	<u>Times</u>	Combined
28 + 16 - 10	28 <mark>+11</mark> - 8	28 +20 - 12

<u>Maneuvers</u>. Sources of uncertainty in the dose reconstruction for the maneuver troops are due to: (1) the residual field intensity, (2) stay time at the 900 yard display area, and (3) distance moved laterally along the 500 mr/hr line. A stay time of 10 minutes was used for the 90-percent confidence limit. The distance the troops moved laterally along the 500 mr/hr line was given in Section 4 as about 500 yards, but due to uncertainty in the exact route of advance towards GZ, this distance could have varied by \pm 100 yards. The calculated film badge doses, with uncertainties, are:

Source of Uncertainty

		Distance Marched along	
Residual	Stay	500 mr/hr	
Field	Times	Line	Combined
106 + 85 - 47	106 + 16 - 14	106 + 14 - 12	106 <mark>+88</mark> - 50

5.2 TOTAL DOSE SUMMARY.

The reconstructed gamma doses for Exercise Desert Rock IV units are presented in Table 4. From the best-estimate doses of Section 4 and the error distributions of Section 5, the mean gamma dose for each unit is calculated. These are presented along with estimated 90-percent confidence limits.

Table 4. Dose summary, Operation Tumbler-Snapper.

<u>Shot</u>	Unit	<u>Total Dose (rem)</u>
CHARLIE	Paratroops	0.011 +.003 002
	Ground troops	0.028 +.020
	Observers	0.019 +.010 006
DOG	Maneuver troops	0.370 +.260
FOX	Observers	0.130 +.050 040
GEORGE	Maneuver troops	0.110 +.090
	Observers	0.028 +.020

.

SECTION 6 FILM BADGE DOSIMETRY

Film badge records for Operation Tumbler-Snapper are available from a film badge list for Shots Fox and George. For Shot Dog, the only indication of exposure is a statement in Reference 6 that integrated doses were less than 500 mrem for most personnel. No other records of exposure are available.

For Shot Fox, 104 records are available. It is not known to which Shot Fox units these records pertain. Aside from six outliers, the badges appear to have a bimodal distribution. One group of 10 badges has a mean of 107 mrem and standard deviation of 31 mrem, which compares very well with the reconstructed dose of 130 + 50 -40 mrem. The second group consists of 88 badges with a mean of 303 mrem and a standard deviation of 51 mrem. The highest reading (isolated) of any Shot Fox film badge was 840 mrem. It is possible that these badges represent undocumented activities of other Shot Fox participants. It is noted that the 104 film badge records available for Shot Fox are a very small sample, with unknown representativeness, of the estimated 1450 observers, and that there are no badges for the largest participating unit, the 701st AIB. However, all film badges indicated exposures significantly less than the maximum permitted dose of 3 rem.

For Shot George, 238 records are available. The badges have a mean dose of 156 mrem and a standard deviation of 27 mrem. The highest reading (one of 9 outliers) was 300 mrem. The calculated film badge dose of $106 \frac{+87}{-48}$ mrem compares well with the actual film badge doses, particularly when the distribution of badge readings is compared with the confidence range of the calculated doses. Reference 6 indicates that the average exposure for this shot was less than 500 mrem.

SECTION 7 CONCLUSIONS

Exercise Desert Rock IV personnel participated in four of the eight test shots of Operation Tumbler-Snapper. No personnel were located closer than 7000 yards from ground zero at the time of the detonations. Moreover, all personnel were in trenches or had similar protection.

Initial radiation dose was insignificant for all participants, due to the large distance from the shot.

Residual radiation doses were very low, ranging from 0.011 rem (Shot Charlie, paratroop unit) to 0.37 rem (Shot Dog participants).

The 50-year bone dose commitment for inhaled radionuclides was determined in Reference 28 to be 0.15 rem or less for all participants.

Calculated doses for all observers and maneuver troops were far less than the maximum allowable dose of 3 rem.

In general, available film badge data correlates well with the calculated gamma doses.

SECTION 8

LIST OF REFERENCES

- 1. "Exercise Desert Rock IV, April-June 1952," Sixth Army, 1952. AD/A078 565*/**.
- "Analysis of Radiation Exposure for Troop Observers, Exercise Desert Rock VI, Operation Teapot," DNA 5354F, Defense Nuclear Agency, 28 April 1981. AD/A121701*/**.
- 3. Letter from Brig. Gen. Herbert B. Loper, Chief, AFSWP, to Director, Division of Military Application, US Atomic Energy Commission, April 3, 1952.**
- 4. Letter from A.R. Luedecke, Deputy Chief, AFSWP, to Director, Division of Military Application, US Atomic Energy Commission, March 7, 1952.**
- 5. Annex ABLE to Operation Order 6-52, Headquarters, Fleet Marine Force, Atlantic, revision of 14 April 1952.**
- 6. "Final Report Tumbler-Snapper," Desert Rock Liaison Section, J-3, Test Command, AFSWP, June 2, 1953.**
- 7. Desert Rock Participation in Shot No. 8, Letter from BGEN Storke to Carroll L. Tyler, Test Manager, US Atomic Energy Commission, 19 May 1952.**
- "Operation Snapper, Final Report," Armed Forces Special Weapons Project, WT-564, 1952. AD/B951 764.*
- 9. Desert Rock IV Letter of Instruction No. 1, Hq Sixth Army, Presidio of San Francisco, CA, 19 March 1952.**
- Memo to Commanding General, Sixth Army, Presidio of San Francisco, Subject: Desert Rock IV, Office, Chief of Army Field Forces, Fort Monroe, VA., 19 March 1952.**
- Annex #3 (Personnel and Vehicles) to Operation Order #3, Exercise Desert Rock IV, Charlie, Headquarters, Camp Desert Rock, Las Vegas, Nevada, 17 April 1952.***
- Operation Order #6, Exercise Desert Rock IV, Fox, Hq. Camp Desert Rock, Las Vegas, Nevada, 8 May, 1952.**
- 13. Shots Able, Baker, Charlie, and Dog, The First Tests of the Tumbler-Snapper Series, 1 April-1 May 1952, DNA 6020F, June 1982. AD/A122 241*/**.

^{*}Available from NTIS; order number appears before the asterisk.

^{**}Available at CIC.

^{***}Not available, see Availability Information page following.

- 14. "Report on Exercise Desert Rock IV, 22 April 1952," US Atomic Energy Commission, Memo from LTC R.P. Campbell, Jr., to: Col. G.F. Schlatter, USAF, April 24, 1952.**
- 15. "Summaries of Shots 1-3, 5, and 7" Clark, J.C. Deputy Test Director, 1952.**
- "Reactions of Troops in Atomic Maneuvers Exercise Desert Rock IV," Operations Research Office, The Johns Hopkins University, Chevy Chase, MD. ORO-T-240. July 1953. AD 026 280*.
- 17. "Aircraft Participation in Tumbler-Snapper," Air Force Special Weapons Center, SWO, D/F to Adjutant General Command Historian, 9 June 1952.**
- 18. "Technical Air Operations, Operation Tumbler-Snapper," WT-568, Air Force Special Weapons Center, Kirtland AFB, NM. January 1953.***
- 19. "Report of Exercise Desert Rock IV," Letter from Commanding Officer, First Provisional Marine Battalion, to Commanding General, Marine Corps Provisional Exercise Unit, Camp Pendleton, 5 May 1952.**
- 20. Memo to Commandant of the Marine Corps, Subject, "Exercise Desert Rock IV -Marine Corps, report on," Headquarters, Marine Corps Provisional Exercise Unit, Camp Pendleton, CA., 17 May 1952.***
- 21. Operation Plan 1-52, Marine Corps Provisional Exercise Unit, Camp Desert Rock, Nevada, April 1952.**
- 22. "Desert Rock IV Reactions of an Armored Infantry Battalion to an Atomic Bomb Maneuver," Human Resources Research Office Technical Report #2, August 1953. AD 016 451*
- 23. Letter from M.W. Boyer, General Manager, AEC, to BGEN H.B. Loper, Chief, AFSWP, approving participation of 1500 service troops in Shot 6, May 1952.**
- 24. "Shots Easy, Fox, George and How, The Final Tests of the Tumbler-Snapper Series, 7 May-5 June 1952," DNA 6021F, June 1982. AD/A122 240*/**.
- 25. "Analysis of Radiation Exposure for Task Force BIG BANG, Shot Galileo, Exercise Desert Rock VII-VIII, Operation Plumbbob," DNA 4772F, Defense Nuclear Agency, 9 April 1980. AD/A085 801*/**.
- 26. "Analysis of Radiation Exposure for Task Force WARRIOR, Shot Smoky, Exercise Desert Rock VII-VIII, Operation Plumbbob," DNA 4747F, Defense Nuclear Agency, 31 May 1979. AD/A070 239*/**.

^{*}Available from NTIS; order number appears before the asterisk.

^{**}Available at CIC.

^{***}Not available, see Availability Information page following.

- 27. "Analysis of Radiation Exposure, 2nd Marine Provisional Atomic Exercise Brigade, Exercise Desert Rock V, Operation Upshot-Knothole," DNA-TR-82-03, 5 February 1982. AD/A124 279*/**.
- 28. "Low Level Internal Dose Screen, Nuclear Test Personnel Review," Volume I, CONUS Tests, DNA-TR-85-317-V1, Defense Nuclear Agency, 10 October 1985.

*Available from NTIS; order number appears before the asterisk.

- **Available at CIC.
- ***Not available, see Availability Information page following.

AVAILABILITY INFORMATION

An availability statement is included at the end of the reference citation for those readers who wish to read or obtain copies of source documents. It is anticipated that some of the documents marked unavailable may subsequently become available during the classification review process. The Coordination and Information Center (CIC) and the National Technical Information Service (NTIS) will be provided declassified DNA-WT documents bearing an EX after the report number.

Source documents bearing an availability statement of NTIS may be purchased from the National Technical Information Service. When ordering by mail or phone, please include both the price code and the NTIS number. The price code appears in parentheses before the NTIS order number.

National Technical Information	Service		
5285 Port Royal Road	Phone:	(703) 487-4650	(Sales Office)
Springfield, VA 22161		(703) 487-4780	(Identification)

Source documents bearing an availability statement of CIC may be ordered or reviewed at the following address:

Department of Energy Coordination and Information Center 3084 S. Highland P.O. Box 14400 Phone: (702) 295-0731 Las Vegas, NV 89114-4400 FTS: 575-0731

DISTRIBUTION LIST

DEPARTMENT OF DEFENSE

ARMED FORCES RADIOBIOLOGY RSCH INST ATTN DEPUTY DIRECTOR ATTN DIRECTOR ATTN SCIENTIFIC DIRECTOR ATTN TECHNICAL LIBRARY ASST SECY OF DEFENSE PUBLIC AFFAIRS ATTN· ASD(PA) ASSISTANT SECRETARY OF DEFENSE ATTN ASD(HA)

DEFENSE INTELLIGENCE AGENCY ATTN· RTS-2B

DEFENSE NUCLEAR AGENCY ATTN. GC ATTN. PAO 10 CYS ATTN STBE 54 CYS ATTN STTI-CA

DEFENSE TECHNICAL INFORMATION CENTER 12 CYS ATTN \cdot DD

DEP UNDER SEC OF DEF FOR RSCH & ENGRG ATTN. DUSDRE RSCH & ADV TECH

FIELD COMMAND DNA DET 2 LAWRENCE LIVERMORE NATIONAL LAB ATTN FC-1

FIELD COMMAND DEFENSE NUCLEAR AGENCY ATTN. FCL 2 CYS ATTN. FCLS ATTN. FCTT W SUMMA ATTN FCTXE ATTN FCTXE

DEPARTMENT OF THE ARMY

HARRY DIAMOND LABORATORIES ATTN⁻ SLCIS-IM-TL 81100 TECH LIB

HQ DEPARTMENT OF THE ARMY 5 CYS ATTN DAAG-ESG-N, NTPR

U S ARMY BALLISTIC RESEARCH LAB ATTN. DRDAR-BLV-R J MALONEY

U S ARMY CTR OF MILITARY HISTORY ATTN. LIBRARY U S ARMY MEDICAL RSCH & DEV CMD ATTN: SGRD-SD

U S ARMY NUCLEAR & CHEMICAL AGENCY ATTN. MONA-ZB C DAVIDSON

WALTER REED ARMY MEDICAL CENTER ATTN. LIBRARY

DEPARTMENT OF THE NAVY

MARINE CORPS HISTORY & MUSEUMS ATTN HISTORICAL DIV

NATIONAL NAVAL MEDICAL CENTER ATTN DEPT OF RADIOLOGY ATTN MEDICAL LIBRARY

NAVAL HISTORICAL CENTER ATTN. DD ALLARD

NAVAL MEDICAL COMMAND ATTN MEDCOM-21 ATTN NM&S-00 ATTN: NM&S-09

NAVAL OCEAN SYSTEMS CENTER ATTN: TECH LIB CODE 9642

NAVAL SEA SYSTEMS COMMAND ATTN: SEA-08 M MILES

NAVAL WEAPONS EVALUATION FACILITY ATTN: CLASSIFIED LIBRARY

OFC OF THE DEPUTY CHIEF OF NAVAL OPS 5 CYS ATTN: NOP 0455

DEPARTMENT OF THE AIR FORCE

AEROSPACE MEDICAL DIVISION, AFSC ATTN. LIBRARY SCL-4

AIR FORCE HISTORICAL RSCH CTR ATTN LIBRARY

AIR FORCE INSTITUTE OF TECHNOLOGY ATTN. LIBRARY/AFIT/LDEE

AIR FORCE NUCLEAR TEST REVIEW 4 CYS ATTN SGPT COL GIBBONS

DEPARTMENT OF THE AIR FORCE (CONTINUED)

AIR FORCE WEAPONS LABORATORY, AFSC ATTN NT ATTN SUL

AIR UNIVERSITY LIBRARY ATTN AUL-LSE

U S AF OCCUPATIONAL & ENV HEALTH LAB 4 CYS ATTN AFNTPR ATTN R2

DEPARTMENT OF ENERGY

DEPARTMENT OF ENERGY ATTN OMA, DP-22

DEPARTMENT OF ENERGY ATTN B CHURCH, HPD

DEPARTMENT OF ENERGY ATTN J THIESEN ER-70 ATTN TECH INFO CTR E-201

UNIVERSITY OF CALIFORNIA LAWRENCE LIVERMORE NATIONAL LAB ATTN L ANSPAUGH ATTN L-53 TECH INFO DEPT LIB ATTN Y NG

LOS ALAMOS NATIONAL LABORATORY ATTN. F601 T DOWLER ATTN ITO D STILLMAN ATTN MS218 P WHALEN

OAK RIDGE NATIONAL LABORATORY ATTN C RICHMOND ATTN G KERR

OAK RIDGE NATIONAL LABORATORY ATTN T JONES

REYNOLDS ELECTRICAL AND ENGR CO, INC ATTN CIC ATTN LST ATTN W BRADY

OTHER GOVERNMENT

CANCER CENTER, NIH ATTN A KNUDSON

CENTRAL INTELLIGENCE AGENCY ATTN OFC OF MED SVCS

CONSUMER PRODUCT SAFETY COMMISSION ATTN M BLOOM ATTN P PRUESS

DEPARTMENT OF COMMERCE ATTN C KUYATT ATTN JHUBBELL ATTN MEHRLICH

DEPT OF HEALTH & HUMAN SERVICES ATTN⁻ OFC OF REG REVIEW

DEPARTMENT OF HEALTH & HUMAN SVCS ATTN⁻ R MURPHY

DEPARTMENT OF LABOR ATTN SWEINER

DEPARTMENT OF TRANSPORTATION ATTN HL REIGHARD

DEPT OF HEALTH & HUMAN SERVICES ATTN. C SILVERMAN HFX-101 ATTN: G JOHNSON HFX-4 ATTN J VILLFORTH HFX-1

ENVIRONMENTAL PROTECTION AGENCY ATTN. P MAGNO ATTN T THORSLUND

ENVIRONMENTAL PROTECTION AGENCY ATTN D ROSENDAUM ANR-458 ATTN. N NELSON ANR-460 ATTN W ELLETT ANR-460 ATTN W MILLS ANR-460

FEDERAL EMERGENCY MANAGEMENT AGENCY ATTN[.] C SIEBENTRITT ATTN. H TOVEY ATTN OFC OF RSCH/NP H TOVEY

LIBRARY OF CONGRESS ATTN SCI & TECH DIV

NASA HEADQUARTERS ATTN M/S SBR-3 P RAMBAUT

NATIONAL CANCER INSTITUTE, NIH ATTN. B WACHOLZ ATTN G BEEBE ATTN V ZEVE

NATIONAL CANCER INSTITUTE, NIH ATTN C LAND ATTN J FRAUMENI ATTN W BLOT

NATIONAL CANCER INSTITUTE, NIH ATTN: J GART

NATIONAL CANCER INSTITUTE, NIH ATTN A RABSON ATTN D PISTENMAA ATTN J WYNGAARDEN

OTHER GOVERNMENT (CONTINUED)

NATIONAL INSTITUTE FOR OCCUPATIONAL ATTN' W MURRAY

NATIONAL INSTITUTES OF HEALTH ATTN LIBRARY ACQ UNIT

NATIONAL LIBRARY OF MEDICINE, NIH ATTN. LIBRARY

NATIONAL SCIENCE FOUNDATION ATTN P HARRLMAN

NATL HEART, LUNG & BLOOD INSTITUTE, NIH ATTN. W ZUKEL

OFFICE ON SMOKING & HEALTH ATTN: J PINNEY

SUBCOMMITTEE OF NUCLEAR REGULATORY ATTN. J CURTISS

U S HOUSE OF REPRESENTATIVES ATTN SUBCOMM ON MIL PER & COMP

U S HOUSE OF REPRESENTATIVES ATTN[.] SUBCOMM ON HEALTH & ENVIR

U S HOUSE OF REPRESENTATIVES 2 CYS ATTN: MAJORITY COUNSEL

U S NUCLEAR REGULATORY COMMISSION ATTN R WHIPP FOR F ARSENAULT ATTN R WHIPP FOR R MINOGUE ATTN R WHIPP FOR W MILLS

U S PUBLIC HEALTH SERVICE ATTN: LIBRARY

U S SENATE ATTN J MCGOVERN

U S SENATE 3 CYS ATTN MAJORITY COUNSEL

U S SENATE ATTN S ULM SENATE COURT

VETERANS ADMIN MEDICAL CENTER ATTN K LEE

VETERANS ADMIN MEDICAL CENTER ATTN. D MCGREGOR

VETERANS ADMIN MEDICAL CENTER ATTN C TESSMER

VETERANS ADMIN WADSWORTH HOSPITAL CTR ATTN T MAKINODAN VETERANS ADMINISTRATION ATTN: A GRAHAM RADIOLOGY ATTN: B POLCARI COMPENSATION ATTN. D BOSCH BVA 2 CYS ATTN D STARBUCK ATTN. L HOBSON

VETERANS ADMINISTRATION HOSPITAL ATTN. R YALOW

VETERANS ADMINISTRATION-RO ATTN DIRECTOR

VETERANS ADMINISTRATION-RO ATTN DIRECTOR

VETERANS ADMINISTRATION-RO ATTN. DIRECTOR

VETERANS ADMINISTRATION-RO ATTN. DIRECTOR

VETERANS ADMINISTRATION-RO ATTN. DIRECTOR

VETERANS ADMINISTRATION-RO ATTN DIRECTOR

VETERANS ADMINISTRATION-RO ATTN: DIRECTOR

VETERANS ADMINISTRATION-RO ATTN DIRECTOR

VETERANS ADMINISTRATION-RO ATTN DIRECTOR

VETERANS ADMINISTRATION-RO ATTN. DIRECTOR

VETERANS ADMINISTRATION-RO ATTN: DIRECTOR

VETERANS ADMINISTRATION-RO ATTN. DIRECTOR

VETERANS ADMINISTRATION-RO ATTN. DIRECTOR

VETERANS ADMINISTRATION-RO ATTN. DIRECTOR

VETERANS ADMINISTRATION-RO ATTN: DIRECTOR

VETERANS ADMINISTRATION-RO ATTN[·] DIRECTOR

VETERANS ADMINISTRATION-RO ATTN DIRECTOR

OTHER GOVERNMENT (CONTINUED)

VETERANS ADMINISTRATION-RO ATTN DIRECTOR

VETERANS ADMINISTRATION-RO ATTN DIRECTOR

VETERANS ADMINISTRATION-RO ATTN DIRECTOR

VETERANS ADMINISTRATION-RO ATTN: DIRECTOR

VETERANS ADMINISTRATION-RO ATTN DIRECTOR

VETERANS ADMINISTRATION-RO ATTN DIRECTOR

VETERANS ADMINISTRATION-RO ATTN DIRECTOR

VETERANS ADMINISTRATION-RO ATTN DIRECTOR

VETERANS ADMINISTRATION-RO ATTN: DIRECTOR

VETERANS ADMINISTRATION-RO ATTN DIRECTOR

VETERANS ADMINISTRATION-RO ATTN DIRECTOR

VETERANS ADMINISTRATION-RO ATTN⁻ DIRECTOR

VETERANS ADMINISTRATION-RO ATTN DIRECTOR VETERANS ADMINISTRATION-RO ATTN DIRECTOR

VETERANS ADMINISTRATION-RO ATTN DIRECTOR

VETERANS ADMINISTRATION-RO ATTN. DIRCTOR

VETERANS ADMINISTRATION-RO ATTN: DIRECTOR

VETERANS ADMINISTRATION-RO ATTN: DIRECTOR

VETERANS ADMINISTRATION-RO ATTN DIRECTOR

VETERANS ADMINISTRATION-RO ATTN DIRECTOR

VETERANS ADMINISTRATION-RO ATTN DIRECTOR

VETERANS ADMINISTRATION-RO ATTN. DIRECTOR

VETERANS ADMINISTRATION-RO ATTN DIRECTOR

VETERANS ADMINISTRATION-RO ATTN: DIRECCTOR

VETERANS ADMINISTRATION-RO ATTN DIRECTOR

VETERANS ADMINISTRATION-RO ATTN. DIRECTOR

VETERANS ADMINISTRATION-RO ATTN DIRECTOR

VETERANS ADMINISTRATION-RO ATTN DIRECTOR

VETERANS ADMINISTRATION-RO ATTN DIRECTOR

VETERANS ADMINISTRATION-RP ATTN DIRECTOR

WHITE HOUSE (THE) ATTN OFC OF POLICY DEV (DP)

DEPARTMENT OF DEFENSE CONTRACTORS

ADVANCED RESEARCH & APPLICATIONS CORP ATTN R ARMISTEAD

BDM CORP ATTN J BRADDOCK **DEPT OF DEFENSE CONTRACTORS (CONTINUED)**

JAYCOR ATTN A NELSON

KAMAN TEMPO ATTN DASIAC

KAMAN TEMPO ATTN· DASIAC

LOUISIANA UNIV SCH OF MED, SHREVEPORT ATTN LIBRARY

NATIONAL ACADEMY OF SCIENCES ATTN C ROBINETTE ATTN S JABLON

NEBRASKA, UNIVERSITY OF ATTN LIBRARY

NORTHROP CORP ATTN Z SHANFIELD

OHIO STATE UNIVERSITY ATTN LIBRARY

PACIFIC-SIERRA RESEARCH CORP ATTN. H BRODE, CHAIRMAN SAGE

R & D ASSOCIATES ATTN C K B LEE

R & D ASSOCIATES ATTN A DEVERILL

RADIATION RESEARCH ASSOCIATES, INC ATTN⁻ N SCHAEFFER

RAND CORP ATTN P DAVIS ATTN TECH LIBRARY

RAND CORP ATTN B BENNETT

SCIENCE APPLICATIONS INTL CORP ATTN C THOMAS 2 CYS ATTN E ORTLIEB 2 CYS ATTN: J GOETZ 2 CYS ATTN J KLEMM ATTN J MCGAHAN 2 CYS ATTN W DETLEFS

SCIENTIFIC INFORMATION SERVICES, INC ATTN: LIBRARY

FOREIGN

CANADIAN EMBASSY ATTN LIBRARY

ATTN LIBRARY INDIAN COUNCIL OF MEDICAL RSCH ATTN. A TASKAR JAPAN-HAWAII CANCER STUDY ATTN G GLOBER MAURICE DELPLA ATTN M DELPLA MCGILL UNIVERSITY ATTN R OSEASOHN PRESIDENTE UMBERTO COLOMBO ATTN: LIBRARY PUERTO RICO SCH OF MEDICINE, UNIV OF ATTN: LIBRARY UNITED KINGDOM SCIENTIFIC MISSION ATTN MILLIASION FOR D FAKLEY 2 CYS ATTN PUBS FOR MRC SO 128 **DIRECTORY OF OTHER** AKRON PUBLIC LIBRARY ATTN: GOVT PUB LIBN ALABAMA, UNIVERSITY OF ATTN. DIR OF LIBS REGIONAL ALASKA, UNIVERSITY OF ATTN DIR OF LIBRARIES ALLEN COUNTY PUBLIC LIBRARY ATTN LIBRARIAN ANAHEIM PUBLIC LIBRARY ATTN LIBRARIAN ARIZONA, UNIVERSITY ATTN. LIBRARIAN ARKANSAS COLLEGE LIBRARY ATTN: LIBRARY ARKANSAS LIBRARY COMM ATTN. LIBRARY ARKANSAS, UNIVERSITY OF ATTN GOVT DOCUMENTS DIV **BEMIDJI STATE COLLEGE** ATTN. LIBRARY BRIGHAM YOUNG UNIVERSITY ATTN DOCS COLLECTION

EDF - RETN 1

BROOKHAVEN NATIONAL LABORATORY ATTN A B BRILL MEDICAL DEPT ATTN: E CRONKITE MEDICAL DEPT ATTN M BENDER MEDICAL DEPT ATTN TECHNICAL LIBRARY ATTN V BOND **BURLINGTON LIBRARY** ATTN LIBRARIAN CALIFORNIA INSTITUTE OF TECHNOLOGY ATTN ELEWIS ATTN R CHRISTY CALIFORNIA STATE LIBRARY (REGIONAL) ATTN LIBRARIAN **CALIFORNIA STATE UNIVERSITY** ATTN LIBRARIAN CALIFORNIA, UNIVERSITY ATTN GOVT DOCUMENTS DEPT CALVIN T RYAN LIBRARY ATTN. GOVT DOCUMENTS DEPT CENTRAL FLORIDA UNIV OF ATTN LIB DOCS DEPT CENTRAL WASHINGTON UNIVERSITY ATTN LIB DOCS SECTION CHARLESTON COUNTY LIBRARY ATTN LIBRARIAN CHARLOTTE & MECHLENBURG COUNTY PUB LIB ATTN E CORRELL CHATTANOOGA HAMILTON CO ATTN LIBRARIAN CHICAGO PUBLIC LIBRARY ATTN GOVTS PUBS DEPT CHICAGO, UNIVERSITY OF ATTN P MEIER COLORADO STATE UNIV LIBS ATTN LIBRARIAN COLORADO, UNIVERSITY OF ATTN LIBRARY

COLUMBIA UNIVERSITY ATTN A BLOOM ATTN LIBRARY

COLUMBIA UNIVERSITY ATTN DIV OF BIOSTATISTICS

ATTN: C/O REECD CORNELL UNIVERSITY ATTN W FEDERER DALLAS PUBLIC LIBRARY ATTN LIBRARIAN DAYTON & MONTGOMERY CITY PUB LIB ATTN LIBRARIAN DECATUR PUBLIC LIBRARY ATTN LIBRARIAN DELTA STATE UNIVERSITY ATTN: LIBRARIAN DETROIT PUBLIC LIBRARY ATTN LIBRARIAN DICKINSON STATE COLLEGE ATTN LIBRARIAN DREW, UNIVERSITY OF ATTN LIBRARY DULUTH PUBLIC LIBRARY ATTN DOCUMENTS SECTION EAST CAROLINA UNIVERSITY ATTN: LIBRARY DOCS DEPT EASTERN BRANCH ATTN. LIBRARIAN EL PASO PUBLIC LIBRARY ATTN DOCS & GENEOLOGY DEPT ENOCH PRATT FREE LIBRARY ATTN DOCS OFFICE **EVANSVILLE & VANDERBURGH COUNTY PUB LIB** ATTN LIBRARIAN FLORIDA STATE UNIVERSITY ATTN DOCUMENTS DEPARTMENT FOND DU LAC PUBLIC LIB ATTN LIBRARIAN FORT HAYS STATE UNIVERSITY ATTN. LIBRARIAN FORT WORTH PUBLIC LIBRARY ATTN LIBRARIAN FRESNO COUNTY FREE LIBRARY ATTN LIBRARIAN

COORDINATION & INFORMATION CTR

GADSEN PUBLIC LIBRARY ATTN LIBRARIAN

GEORGIA, MEDICAL COLLEGE OF ATTN L STODDARD

GRAND RAPIDS PUBLIC LIBRARY ATTN: DIR OF LIBRARIES

GREENVILLE COUNTY LIBRARY ATTN: LIBRARIAN

GUAM RFK MEMORIAL UNIVERSITY LIB ATTN: FED DEPOS COLLECTION

HARVARD SCHOOL OF PUBLIC HEALTH ATTN: J BAILOR ATTN: LIBRARY ATTN: R REED

HARVARD SCHOOL OF PUBLIC HEALTH ATTN: B MACMAHON

HARVARD UNIVERSITY ATTN. W COCHRAN

HAWAII, UNIVERSITY OF ATTN: Y MATSUMOTO

HOPKINSVILLE COMM COLL ATTN: LIBRARIAN

IDAHO STATE UNIVERSITY LIBRARY ATTN DOC DEPARTMENT

IDAHO, UNIVERSITY OF ATTN DIR OF LIBRARIES REGIONAL

ILLINOIS STATE LIBRARY (REGIONAL) ATTN GOVT DOCS BR

INDIANA STATE LIBRARY (REGIONAL) ATTN SERIAL SECTION

INDIANA UNIVERSITY ATTN⁻ F PUTNAM

IOWA STATE UNIVERSITY ATTN: T BANCROFT

JOHNS HOPKINS UNIVERSITY ATTN A KIMBALL ATTN: R SELTSER

KANSAS CITY PUBLIC LIBRARY ATTN: DOCUMENTS DIV

KANSAS STATE LIBRARY ATTN: LIBRARIAN KANSAS STATE UNIV LIBRARY ATTN: DOCUMENTS DEPT

KANSAS UNIV OF AGRI & APPLIED SCIENCE ATTN H FRYER

KENTUCKY DEPT OF LIBRARY & ARCHIVES ATTN DOCUMENTS SECTION

KENTUCKY, UNIVERSITY OF ATTN. DIR OF LIBS REGIONAL

KINGSTON HOSPITAL ATTN⁻ K JOHNSON

LOS ANGELES PUBLIC LIBRARY ATTN. SERIALS DIV U S DOCS

LOUISIANA STATE UNIVERSITY ATTN⁻ DIR OF LIBS REGIONAL

MAINE UNIVERSITY, OF ATTN: LIBRARIAN

MANKATO STATE COLLEGE ATTN: GOVT PUBLICATIONS

MANTOR LIBRARY ATTN DIR OF LIBRARIES

MARATHON COUNTY PUBLIC LIBRARY ATTN⁻ LIBRARIAN

MARYLAND UNIVERSITY OF ATTN MCKELDIN LIBR DOCS DIV

MAUI PUBLIC LIBRARY ATTN LIBRARIAN

MEMORIAL HOSP FOR CANCER & ALLIED DISEASES ATTN[.] P LIEBERMAN

MEMORIAL SLOAN-KETTERING CANCER CENTER ATTN J LAUGHLIN ATTN P MARKS

MEMPHIS SHELBY COUNTY PUB LIB & INFO CTR ATTN. LIBRARIAN

MERCER UNIVERSITY ATTN LIBRARIAN

MERCK, SHARP & DOHME INTL ATTN A BEARN

MESA COUNTY PUBLIC LIBRARY ATTN LIBRARIAN

MIAMI PUBLIC LIBRARY ATTN: DOCUMENTS DIV

MIAMI, UNIVERSITY OF ATTN P HODES

MICHIGAN MEDICAL SCHOOL, UNIV OF ATTN J NEEL

MICHIGAN STATE LIBRARY ATTN LIBRARIAN

MICHIGAN, UNIVERSITY OF ATTN R CORNELL

MICHIGAN, UNIVERSITY OF ATTN F MOORE

MINNESOTA DEPT OF HEALTH ATTN D LILIENFELD

MINNESOTA, UNIVERSITY OF ATTN J BEARMAN ATTN L SCHUMAN ATTN LIBRARY

MINOT STATE COLLEGE ATTN LIBRARIAN

MISSOURI, UNIVERSITY LIBRARY ATTN GOVERNMENT DOCS

MONTANA STATE LIBRARY ATTN LIBRARIAN

NASSAU LIBRARY SYSTEM ATTN LIBRARIAN

NATL COUNCIL ON RADIATION ATTN W SINCLAIR

NATRONA COUNTY PUBLIC LIBRARY ATTN LIBRARIAN

NEW HAMPSIRE UNIVERSITY LIB ATTN LIBRARIAN

NEW MEXICO, UNIV OF ATTN C KEY ATTN R ANDERSON

NEW YORK PUBLIC LIBRARY ATTN LIBRARIAN

NEW YORK STATE LIBRARY ATTN DOCS DOCS CONT CULTURAL ED CTR

NEW YORK STATE UNIV OF ATTN LIB DOCS SEC

NEW YORK UNIV MEDICAL CENTER ATTN N NELSON

ATTN A UPTON ATTN. B POSTERNACK ATTN LIBRARY ATTN. M EISENBUD NEWARK FREE LIBRARY ATTN LIBRARIAN NORTH CAROLINA UNIV AT WILMINGTON ATTN LIBRARIAN NORTH CAROLINA, UNIVERSITY OF ATTN B GREENBERG ATTN. LIBRARY FOR DEAN NORTHERN ARIZONA UNIVERSITY LIB ATTN. GOVT DOCUMENTS DEPT NORTHERN IOWA UNIVERSITY ATTN LIBRARY NORTHERN MICHIGAN UNIV ATTN DOCUMENTS NORTHERN MONTANA COLLEGE LIBRARY ATTN LIBRARIAN NORTHWESTERN MICHIGAN COLLEGE ATTN LIBRARIAN NORTHWESTERN UNIVERSITY ATTN: H CEMBER OAK RIDGE ASSOCIATED UNIVERSITIES ATTN DLUSHBAUGH ATTN E TOMPKINS ATTN J TOTTER OHIO STATE LIBRARY ATTN LIBRARIAN OKLAHOMA DEPT OF LIBS ATTN US GOVT DOCUMENTS OKLAHOMA, UNIVERSITY OF ATTN PANDERSON OREGON STATE LIBRARY ATTN LIBRARIAN OREGON, UNIVERSITY OF ATTN DOCUMENTS SECTION OREGON, UNIVERSITY OF ATTN B PIROFSKY PACIFIC NORTHWEST LABORATORY ATTN S MARKS

NEW YORK UNIVERSITY

PENNSYLVANIA STATE LIBRARY ATTN: GOVT PUBS SEC

PENNSYLVANIA UNIV HOSPITAL ATTN[.] S BAUM

PENNSYLVANIA, UNIV OF ATTN P NOWELL

PEORIA PUBLIC LIBRARY ATTN. BUS, SCI & TECH DEPT

PHILADELPHIA FREE LIB OF ATTN GOVT PUBS DEPT

PITTSBURGH, UNIV OF ATTN E RADFORD ATTN LIBRARY

PITTSBURGH, UNIVERSITY OF ATTN: N WALD

PUBLIC LIB CINCINNATI & HAMILTON COUNTY ATTN⁻ LIBRARIAN

RAPID CITY PUBLIC LIBRARY ATTN LIBRARIAN

READING PUBLIC LIBRARY ATTN LIBRARIAN

RHODE ISLAND LIBRARY, UNIVERSITY OF ATTN. GOVT PUBS OFFICE

ROCHESTER UNIV MEDICAL CTR ATTN C ODOROFF ATTN G CASARETT

ROCHESTER UNIV OF LIB ATTN DOCUMENTS SECTION

ROCHESTER, UNIVERSITY OF ATTN: L HEMPELMANN

SAINT FRANCIS HOSPITAL ATTN: R BLAISDELL

SAN ANTONIO PUBLIC LIBRARY ATTN BUS SCI & TECH DEPT

SCOTTSBLUFF PUBLIC LIBRARY ATTN LIBRARIAN

SCRANTON PUBLIC LIBRARY ATTN LIBRARIAN

SILAS BRONSON PUBLIC LIBRARY ATTN LIBRARIAN SIMON SCHWOB MEM LIB ATTN. LIBRARIAN

SIOUX CITY PUBLIC LIBRARY ATTN LIBRARIAN

SOUTH CAROLILNA, MEDICAL UNIV OF ATTN P LIU

SOUTH DAKOTA STATE LIBRARY ATTN. FED DOCS DEPT

SOUTHEASTERN MASSACHUSETTS UNIV LIB ATTN. DOCUMENTS SEC

SOUTHERN ALABAMA, UNIVERSITY OF ATTN⁻ LIBRARIAN

SOUTHERN CALIFORNIA, UNIV OF ATTN: J BIRREN

SOUTHERN ILLINOIS UNIVERSITY ATTN DOCUMENTS CTR

SOUTHERN MISSISSIPPI UNIV OF ATTN LIBRARY

SOUTHERN OREGON COLLEGE ATTN LIBRARY

SOUTHERN UTAH STATE COLLEGE LIBRARY ATTN DOCUMENTS DEPT

SOUTHWEST MISSOURI STATE COLLEGE ATTN. LIBRARY

SPOKANE PUBLIC LIBRARY ATTN REFERENCE DEPT

SPRINGFIELD CITY LIBRARY ATTN: DOCUMENTS SECTION

STANFORD UNIV MEDICAL CENTER ATTN J BROWN

STANFORD UNIVERSITY ATTN. L MOSES

STANFORD UNIVERSITY HOSPITAL ATTN: D DORFMAN

STATE LIBR OF MASS ATTN LIBRARIAN

TACOMA PUBLIC LIBRARY ATTN: LIBRARIAN

TEXAS A & M UNIVERSITY ATTN R STONE

TEXAS AT AUSTIN, UNIV OF ATTN: H SUTTON

TEXAS STATE LIBRARY ATTN US DOCS SECTION

TEXAS TECH UNIVERSITY LIBRARY ATTN GOVT DOCUMENTS DEPT

TEXAS, UNIVERSITY OF ATTN C S COOK

TEXAS, UNIVERSITY OF ATTN. R STALLONES

TEXAS, UNIVERSITY OF ATTN: W SUTOW

TEXAS, UNIVERSITY OF ATTN G TAYLOR

TOLEDO PUBLIC LIBRARY ATTN SOCIAL SCI DEPT

TRENTON FREE PUBLIC LIBRARY ATTN LIBRARIAN

TULSA UNIVERSITY, OF ATTN LIBRARIAN

UTAH STATE UNIVERSITY ATTN LIBRARIAN

UTAH, UNIVERSITY OF ATTN: LIBRARY

UTAH, UNIVERSITY OF ATTN C MAYS ATTN. E WRENN ATTN L LYONS ATTN: LIBRARY

VANDERBILT UNIVERSITY ATTN: R QUINN VERMONT, UNIVERSITY OF ATTN DIR OF LIBRARIES

VIRGINIA STATE LIBRARY ATTN SERIALS SECTION

VIRGINIA, UNIVERSITY OF ATTN: PUBLIC DOCUMENTS

WASHINGTON STATE LIBRARY ATTN DOCUMENTS SECTION

WASHINGTON, UNIVERSITY OF ATTN D THOMPSON

WASHINGTON, UNIVERSITY OF ATTN: A MOTULSKY

WEST VIRGINIA COLL OF GRAD STUDIES LIB ATTN XXXXX

WEST VIRGINIA, UNIVERSITY OF ATTN: DIR OF LIBS REGIONAL

WESTERN WYOMING COMMUNITY COLLEGE LIB ATTN·XXXXX

WISCONSIN, UNIVERSITY OF ATTN ACQUISITIONS DEPT

WISCONSIN, UNIVERSITY OF ATTN: J CROW

WORCESTER PUBLIC LIBRARY ATTN LIBRARIAN

YALE UNIVERSITY ATTN DIR OF LIBRARIES

YALE UNIVERSITY SCH OF MEDICINE ATTN J MEIGS ATTN LIBRARY